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ABSTRACT

A study of 60 elementary and secondary math and science teachers who were nominated by their peers as effective microcomputer-using teachers was conducted to describe how peer-nominated teachers use microcomputers instructionally, and how these uses vary as a function of teacher characteristics (e.g., knowledge, attitudes) and other background variables (e.g., learning environments). The primary method of data collection was personal, semi-structured interviews; however, observational techniques were also used to note the physical context of microcomputer use and examine courseware used during the observation period. In addition, biographical data was obtained from the teachers through a self-administered questionnaire which provided information on their educational and teaching background, and their attitudes toward computers. Homogeneous clusters of teachers were formed on the basis of their patterns of microcomputer-based instruction, revealing four characteristic patterns of use: orchestration, enrichment, adjunct instruction, and drill and practice. Analysis of the data indicated that teachers' attitudes toward microcomputers were unrelated to the patterns of microcomputer-based instruction that were identified; there were no systematic differences between patterns of use according to the average percent of coursework taken relating to computers except for teachers in the drill and practice cluster; patterns of microcomputer-based instruction were unrelated to teachers' experience in using microcomputers, to teaching other teachers about them, or to their facility with computer languages; patterns of instructional microcomputer use were unrelated to district and school policies regarding their use; and patterns of computer-based instruction were unrelated to organizational variables such as the number and location of microcomputers. It is suggested that data on student achievement and motivation would help to determine whether these different styles of teaching with microcomputers produce different outcomes. A list of references completes the document. (JB)

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HOW EFFECTIVE TEACHERS USE MICROCOMPUTERS FOR INSTRUCTION

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April 1984

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How Effective Teachers Use Microcomputers for Instruction

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Microcomputers hold great promise for improving classroom instruction. At a time when American education is perceived as less than excellent, microcomputers are viewed as an important way to supplement teaching capability in schools (OTA, 1982). Major problems impede the widespread implementation of microcomputers as an instructional tool, however. Little is known regarding how they may be best used instructionally, few training programs exist for educating teachers to use them, and the amount, quality, and coverage of instructional software (courseware) is inadequate at present (Hall, 1981; OTA, 1982; Romberg & Price, 1981).

These barriers derive from a general lack of knowledge of how to coordinate microcomputer technology preparatory to and during classroom instruction. In this paper, we report results from a study designed to address this knowledge gap. This study, entitled "Teachers' Instructional Uses of Microcomputers in Mathematics and Science

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Instruction," sponsored by the National Institute of Education and The Rand Corporation, had three goals. The first was to describe how teachers who are nominated by their peers as especially effective microcomputer-using teachers use the technology instructionally, and how these uses vary as a function of teacher characteristics (e.g., knowledge, attitudes) and other background variables (e.g., learning environments). The second and third goals were to recommend policies based on the experience and recommendations of these exemplary teachers. One set of recommendations pertains, to the content and form of inservice staff development for educating teachers in the implementation and use of microcomputers. The other set recommends features of educational courseware that may heighten their usefulness to teachers and contribute to high quality classroom instruction.

THEORETICAL FRAMEWORK

This paper speaks to the first goal and describes patterns of instructional microcomputer use in light of evidence from a study of 60 elementary and secondary math and science teachers nominated by their peers as effective microcomputer-using teachers. In addition, we describe the contribution of certain background factors that may be associated with these various patterns of instructional microcomputer use: teacher subject-matter and computer knowledge, district and school policies, and classroom contexts. (See Stasz et al., 1984 and Feibel et al., 1984 for policy recommendations regarding staff development and courseware, respectively.)

To characterize instructional microcomputer use, we adapt a theoretical perspective referred to as "teacher decision making" that describes the process of instruction as it occurs in the classroom (Shavelson & Stern, 1981). The basic premise of the decision-making approach is that instruction is an ongoing process, under the active direction of teachers. Instruction is viewed as multifaceted, with goals, content, activities, and teaching methods orchestrated by teachers in order to provide a flow of activity toward hoped-for outcomes. Teachers' plans are a central focus of this conceptualization. In formulating and evaluating plans, teachers integrate information about students, the subject matter, and the

classroom and school environment in order to reach judgments or decisions that guide instructional activities. Furthermore, teachers monitor ongoing activities. If activities are proceeding as planned, teachers concentrate on maintaining the flow of activity; otherwise, they activate a routine for handling unplanned events. A final monitoring loop occurs when teachers evaluate the outcomes of instruction in order to improve planning.

This framework helps us to recognize patterns of microcomputer use because it suggests specific teaching decisions and tasks in which microcomputers may play a role. We first assume that microcomputer use fits within teachers' ongoing planning and decision-making processes. Given this assumption, the decision-making framework suggests that classroom microcomputer use should be viewed with respect to its *integration* within teachers' ongoing decision processes. Several possible areas for integration can be identified (Winkler & Shavelson, 1983). Microcomputer-based learning activities can be examined with respect to: (a) instructional goals teachers have for students who use them (e.g., achievement, motivational, social); (b) features of the curriculum with which they are coordinated (e.g., subject matter concepts, other course materials and activities); (c) learning activities surrounding their use (e.g., types of courseware assigned, student groupings); (d) pedagogical consequences of their use (e.g., extensiveness of use); and (e) the degree to which they are monitored and may change in response to feedback.

The teachers' decision-making perspective also suggests several important inputs to these decisions and activities. These include: the district, school, and classroom context; and teachers' characteristics including their attitudes and knowledge. Together, the above variables yield a conceptual model, in which various combinations of instructional decisions and tasks using microcomputers are a function of teacher characteristics and contextual variables.

METHOD

Sample

We sought to identify patterns and concomitants of instructional microcomputer use through an intensive study during 1983 of public school teachers who were nominated as "exemplary" users of microcomputers in mathematics or science instruction. Teachers were the primary sampling unit, and we relied on a "snowball" procedure that solicited nominations of highly regarded teachers from experts in the field: officials in government and education; administrators of educational computing organizations; district, school, and teacher contacts. Suggestions were followed up through direct telephone contacts and successive screening of candidates, districts, and schools. Teachers nominated as exemplary were invited to participate if they currently used microcomputers as part of regular classroom instruction in mathematics or science and were responsible for determining the content and form of the microcomputer-based learning activities.

We attempted to achieve an optimal mix among curriculum (mathematics and science), grade level (elementary and secondary), student characteristics (ability and socioeconomic level), and the amount and kind of district support for classroom microcomputer use. However, in practice, our selection of teachers, schools, and districts was driven in large part by our ability to locate elementary and secondary teachers of mathematics or science who fulfilled even these minimal selection criteria. It is interesting to note that we had hoped to sample neatly in the reverse fashion, nesting microcomputer-using teachers within grade levels and balancing across subject matters within a few school districts. This top down, hierarchical sampling plan proved unrealistic, even in a state touted for pioneering the microcomputer industry and implementing the use of these computers in the schools of "Silicon Valley." Our initial contacts with districts, schools, and teachers indicated that while microcomputers were used occasionally to teach programming or foster "computer literacy," they were used sparsely and infrequently for mathematics or science *instruction*. Moreover, microcomputer-using teachers described as "successful" seemed to vanish from the classroom to administrative

positions responsible for coordinating district computer use or to positions in private industry. We termed this phenomenon the *"vanishing computer-using teacher."*

Procedures

Once teachers, districts, and schools were selected and scheduled to participate in the study, most of the data collection occurred on-site. The primary method of data collection was personal, semi-structured interviews. Each interview was conducted by a single interviewer, who interviewed teachers selected to participate, as well as someone knowledgeable about school and district policies regarding microcomputer use. Teachers were asked about their general instructional decisions and practices, uses of microcomputers for instruction, and the classroom context. The school principal was usually interviewed regarding school policies; district-level respondents included assistant superintendents, curriculum coordinators, and, occasionally, designated computer coordinators. Interviews with respondents lasted approximately one hour.

Interviews were augmented with other methods of data collection. We observed how microcomputers were used instructionally in the given learning environment, typically for one class period of about 50 minutes. We also noted the physical context of microcomputer use (i.e., the number, type, and location of available equipment) and examined the courseware used during the observation period. In addition, through a parallel study funded by The Rand Corporation, we obtained biographical data from teachers through a self-administered questionnaire. This provided information on their educational and teaching background, and their experiences with and attitudes toward computers. Questionnaires were distributed to respondents prior to fieldwork and were returned by mail or retrieved during site visits. Questionnaires were returned by all the teachers in the sample.

At the conclusion of each site visit, interviewers translated their detailed observational and interview notes onto an extensive questionnaire (rather than writing a formal case study). The questionnaire contained both closed and open-ended items that elicited data with respect to key variables under study.

Plan of Analysis

As discussed above, our goal of analysis is to characterize patterns of instructional microcomputer use with respect to their integration into ongoing classroom instruction, and to examine whether these patterns vary according to characteristics of teachers and learning contexts. In order to identify *patterns* of microcomputer-based instruction employed by teachers nominated as exemplary, we (1) identified specific instructional decisions and tasks with which microcomputer-based learning activities may be integrated; (2) created a profile for each teacher according to those characteristics; (3) formed statistically homogeneous *clusters* of teachers on a subset of those characteristics; (4) provided preliminary interpretations of the resulting teacher clusters on the basis of the selected characteristics; (5) validated and extended cluster interpretations using additional characteristics of instructional microcomputer use; and (6) investigated which if any characteristics of teachers and learning environments were related to cluster membership.

For the purpose of developing and validating teacher clusters, we created profiles for teachers' microcomputer-based instruction according to fourteen variables that indicated integration of microcomputers into classroom instruction. The first five variables related to teachers' instructional goals and indexed the degree to which they stressed microcomputer use for *mastery* of basic skills, *cognitive* understanding, *motivation*, and *management*; a fifth variable indicated whether or not teachers viewed students' use of microcomputers as a *unique goal*. Three variables were related to features of the curriculum: the degree to which teachers *coordinated* computer-based activities with other learning activities, the degree to which interviewers judged they had *integrated* microcomputer activities with subject matter topics; and whether microcomputers were used by students in the class for *other activities* than mathematics or science instruction. Three variables indexed microcomputer-based instructional activities: the number of different instructional *modes* used (e.g., drill and practice, tutorial, simulation), the number of students typically assigned to the computer (*group size*), and whether or not students were assigned *equal time* on

the computer. Pedagogical consequences were assessed through two variables: the first measured the extent to which the microcomputer was used for instruction (*instructional use*). The second consisted of a summary rating by the interviewer of how *successful* the teacher seemed to be at instructional microcomputer use. The last variable examined as part of the cluster analysis was whether teachers had modified their instruction based on feedback (*change use*).

To investigate whether cluster membership differed according to characteristics of teachers and learning contexts, we compared clusters on variables assessing teachers' attitudes toward microcomputers, knowledge of the subject matter and of microcomputers, district and school policies supporting instructional microcomputer use, and characteristics of students served. Teacher attitudes were measured on an 8-item Likert-type rating scales developed for this research. In lieu of direct and extensive testing of teachers' subject-matter knowledge, something not feasible in this study, we settled for a proxy measure of knowledge. Teachers were asked to indicate the percent of their undergraduate coursework spent in science, mathematics, computer science, social science, humanities, and education. Computer knowledge was also measured non-reactively via teachers' self-reports of how extensively they had used computer hardware and courseware, whether they had served as a resource person for their schools or as an instructor for staff development, and how many programming languages they had used. In addition, interviewers rated each teacher's courseware and hardware knowledge.

Measures of district and school policies touched on areas such as the extent to which the districts supported the implementation and the instructional use of microcomputers, and on the extent to which the schools (principals) supported and provided incentives for microcomputer use. Finally, measures of classroom context included the number of microcomputers available for instruction and their proximity to the teachers' classrooms. Since elementary schools are organized around self-contained classrooms and secondary-school classrooms are organized by subject matter, we examined this grade-level distinction as well. Classroom composition consisted of teachers' estimates of the percent of minority students in their classes and the ability level of their students.

RESULTS

Characteristics of the Fieldwork Sample

Our procedures for locating candidate teachers, districts, and schools produced a varied collection of microcomputer-using teachers and learning environments. The final sample consisted of 60 teachers, 25 districts, and 49 schools, based on initial contacts with 124 teachers nominated as exemplary. All respondents in the final sample fulfilled the minimal definition of using microcomputers as part of ongoing instruction in math, science, or both and of making decisions about the form and content of the microcomputer-based learning activities. The remaining teachers either did not fulfill this minimal definition, or they were not currently using microcomputers in instruction, or they did not return a biographical questionnaire.

Teachers in the final sample, based on information provided in their biographical questionnaire, exhibited considerable diversity in background. Their teaching experience ranged from 2 to 38 years with an average of 15.8 years. On average, 40 percent of their undergraduate coursework was taken in science and mathematics, 20 percent in the humanities, and 15 percent in the social sciences. Virtually all held positive attitudes toward computers.

Overall, teachers indicated that their students were about average in ability (mean=2.03 on a 3 point scale) but the ability composition of individual classrooms varied from low to high (standard deviation of 0.71). Classrooms were comprised of 38 percent minority on average, but this figure varied greatly from one classroom to another with a standard deviation of 32.31. Indeed, the percent minority ranged from 0 to 98 percent with a mode of 0 and a median of 32.5.

Districts and schools also proved to be considerably diverse in characteristics and policies. Of the 25 districts, 14 were unified school districts, 7 were elementary, and 4 were secondary. Students served in the districts ranged from 5 to roughly 90 percent minority, and their performance on statewide measures of reading and mathematics achievement covered the first to fifth quintiles. The number of microcomputers available for instruction in the districts ranged from 10 to 98 with a mean of 59 and a standard deviation of 38. Districts

differed greatly in the manner by which microcomputers had been introduced into instruction; they also provided various degrees of support for their use, ranging from a good deal to none at all. Likewise, schools also varied in the number of microcomputers available for instruction (1 to 55 with an average of about 12) and in the resources they provided for microcomputer-based instruction.

Patterns of Instructional Microcomputer Use

Initial Cluster Analysis. In order to examine the underlying relationships among the indicators of microcomputer use defined above, and recognizing that various combinations of these variables were possible, we used cluster analysis to group together teachers with similar repertoires of use and to distinguish them as clearly as possible from teachers with other repertoires. The cluster analysis was carried out initially on 6 of the 14 variables characterizing instructional microcomputer use--Mastery, Unique-Goal, Coordination, Modes, Group Size, and Change Use. The remaining variables were reserved to cross-validate the clusters and our interpretations of what each represented.

A two-stage cluster analysis was conducted on the 6 variables following Kettenring, Rogers, Smith, and Warner (1976), ultimately yielding four interpretable clusters. The first stage used Ward's procedure (see Hartigan, 1975) with standardized scores on the 6 variables. This procedure minimizes the within-cluster variance among teachers on the six variables while maximizing the between-cluster (centroid) variance. In this way, the 60 teachers were placed into 13 well-defined clusters. The results of Ward's procedure were verified with an average-link algorithm (see Hartigan, 1975). The 13 clusters were reduced to 4 with Johnson's (1967) hierarchical clustering method using the single-link criterion. In this way, the thirteen clusters were merged, one at a time, into the final four clusters. The results of the single-link method were verified with an average-link method.

Table 1 presents the cluster means for each of the six variables entering the cluster analysis. If the cluster analysis were successful, the clusters should differ significantly on each variable. We used a one-way analysis of variance to statistically test for differences among

the cluster means on each of the 6 variables, followed by pairwise post-hoc comparisons using Tukey's method. As expected, the clusters differed significantly on each variable (alpha=0.05).

Table 1

VARIABLES ENTERING CLUSTER ANALYSIS
MEANS AND (STANDARD DEVIATIONS)

Variable	Cluster 1 (n=18)	2 (n=23)	3 (n=14)	4 (n=5)	All (n=60)	Statistical Significance
Mastery goal	2.83 (1.25)	1.78 (1.09)	2.29 (1.20)	3.00 (1.00)	2.32 (1.23)	(a)
Degree of coordination	3.53 (0.51) (n=17)	1.67 (0.86) (n=21)	2.50 (1.02)	3.40 (0.55)	2.58 (1.12) (n=57)	(b)
Unique goal	0.83 (0.38)	0.43 (0.51)	0.00 (0.00)	0.00 (0.00)	0.42 (0.50)	(c)
Number of modes	3.83 (1.34)	2.57 (1.04)	2.57 (1.02)	1.80 (0.84)	2.88 1.28	(d)
Group size	1.41 (0.51) (n=17)	1.23 (0.43) (n=22)	2.00 (0.00)	1.00 (0.00) (n=4)	1.46 (0.50) (n=57)	(e)
Change use	0.78 (0.43)	0.74 (0.45)	0.79 (0.43)	0.00 (0.00)	0.70 0.46	(f)

Cluster sizes are indicated in cells with missing data
Higher values indicate more positive rating or larger number
Group differences on each measure are statistically significant at 0.05 based on one-way analysis of variance. Pair-wise differences between cluster means are statistically significant at 0.05 as follows:

(a) Cluster 1 differs significantly from cluster 2
(b) Clusters 1, 3, and 4 differ significantly from cluster 2, and cluster 1 differs significantly from cluster 3
(c) Cluster 1 differs significantly from the other clusters, and cluster 2 differs significantly from groups 3 and 4
(d) Cluster 1 differs significantly from the other clusters
(e) Cluster 3 differs significantly from the other clusters
(f) Cluster 4 differs significantly from the other clusters

Results indicated that teachers in clusters 1 and 4 tended to use microcomputers to help students master basic skills to a greater extent than did groups 2 and 3. Both groups also tended to coordinate classroom activities (e.g., lectures, readings from texts) with microcomputer activities to a greater extent than did teachers in clusters 2 and 3. The use of the microcomputer as an activity for students in its own right, in addition to being an instructional tool (Unique Goal), distinguished teachers in cluster 1 from the other teachers, and group 2 from groups 3 and 4. Teachers in cluster 1 tended to use a larger number of different instructional modes (e.g. drill and practice, simulation), than did teachers in the other three clusters. Teachers in cluster 3 unanimously grouped two or more students for computer use while those in cluster 4 did not group students; teachers in clusters 1 and 2 fell in between. Finally, the methods of microcomputer use tended not to change for teachers in cluster 4, while three-fourths of the teachers in the other three clusters modified their practices on the basis of feedback.

From this pattern of differences among the four clusters, we tentatively labeled the method of microcomputer use defined by cluster 1 as "orchestrated." Teachers in this cluster used many different forms of courseware for instruction. They stressed mastery of basic skills as a goal of microcomputer use but also held students' use of microcomputers as a *unique* goal. They tended to coordinate microcomputer activities with other curricular activities, and they changed instruction based on feedback.

The pattern of microcomputer use suggested by cluster 2 was tentatively labeled "enrichment." Teachers in this cluster were least inclined to coordinate microcomputer-based instruction with other classroom activities or to use the microcomputer to help students master basic skills. However, they emphasized the goal of encouraging student microcomputer use in its own right, and they tended to assign fewer numbers of students to microcomputer activities. Thus, their instructional computer use resembles that of fostering computer literacy in the context of instruction.

Cluster 3 was tentatively termed "grouping." These teachers were distinguished by their grouping decisions: they provided computer-based instruction to students in groups of two or more. Otherwise, their instructional uses are not especially notable; they are at the mean of the four clusters on coordination of microcomputer activities and emphasis of mastery of basic skills.

Cluster 4 was tentatively labeled "drill and practice." These teachers tended to coordinate computer activities with class activities, stress mastery of basic skills while holding no unique goals for microcomputer use, and to view microcomputer-based learning as an activity for individual students. They tended *not* to change their instructional practices or use multiple instructional modes.

Validation of the Cluster Analysis. These interpretations are tentative, but their validity can be tested by examining how the groups may differ on the remaining variables related to instructional microcomputer use that did not enter into the cluster analysis. Table 2 provides the pertinent data. Cluster 1 is distinguished from the other clusters by the degree to which the microcomputer was used for instruction and the importance placed on cognitive goals for instructional microcomputer use. In conjunction with the findings from Table 1, the "orchestration" label continues to fit this group of teachers. Furthermore, interviewers' judgments of success and integration support this interpretation: teachers in cluster 1 were viewed as more successful overall and their instruction more integrated than that of the teachers in the other clusters.

The "enrichment" label applied to Cluster 2 receives additional support. These teachers were least inclined to try to achieve broad coverage of the subject matter with the microcomputer (Instructional Use in Table 2); indeed, they are most likely to try to bring the microcomputer into other facets of instruction such as word-processing or instruction in other subject-matter areas. Thus, the microcomputer seems to be used to enrich academic instruction, within an overall goal of providing students with opportunities to become familiar with the microcomputer.

Table 2

ADDITIONAL INDICATORS OF MICROCOMPUTER USE
MEANS AND (STANDARD DEVIATIONS)

Variable	Cluster 1 (n=18)	Cluster 2 (n=23)	Cluster 3 (n=14)	Cluster 4 (n=5)	All (n=60)	Statistical Significance
Cognitive goal	2.89 (1.37)	2.39 (1.34)	2.86 (0.86)	1.20 (0.45)	2.55 (1.27)	(a)
Motivation goal	2.78 (1.48)	1.91 (1.24)	2.29 (1.38)	2.20 (1.30)	2.28 (1.37)	NS
Management goal	1.33 (0.97)	1.22 (0.74)	1.21 (0.80)	1.00 (0.00)	1.23 (0.79)	NS
Integration rating	3.44 (0.70)	2.35 (0.88) (n=20)	2.33 (0.98) (n=12)	3.40 (0.89)	2.80 (0.99) (n=55)	(b)
Other activities	0.56 (0.51)	0.74 (0.45)	0.29 (0.47)	0.00 (0.0)	0.52 (0.50)	(c)
Equal time	0.59 (0.51) (n=17)	0.91 (0.29) (n=22)	0.69 (0.48) (n=13)	0.75 (0.50) (n=4)	0.75 (0.44) (n=56)	NS
Instructional use	3.33 (0.84)	2.45 (0.69) (n=20)	2.64 (0.74)	3.60 (0.89)	2.88 (0.87) (n=57)	(d)
Success rating	3.33 (0.65)	2.73 (0.63) (n=22)	2.64 (0.84)	2.40 (0.89)	2.78 (0.83) (n=59)	(e)

Cluster sizes are indicated in cells with missing data
Higher values indicate more positive rating
Group differences on each measure are statistically significant at 0.05 based on one-way analysis of variance when indicated. Pair-wise differences between cluster means are statistically significant at 0.05 as follows:

(a) Cluster 1 differs significantly from cluster 4
(b) Cluster 1 differs significantly from clusters 2 and 3
(c) Cluster 2 differs significantly from clusters 3 and 4
(d) Cluster 2 differs significantly from clusters 1 and 4
(e) Overall F is significant but pairwise comparisons are not

The interpretation of cluster 3 as "grouping" was modified to "adjunct instruction" based on data in Table 2. These teachers tended to confine microcomputer use to the given subject matter areas and to stress acquisition of conceptual knowledge. But their microcomputer use seems constrained. Unlike teachers in cluster 2, who try to use the microcomputer to provide a wide range, even if a limited amount, of instruction, the approach of the Cluster 3 teachers appears to be to selectively augment certain lessons, stressing conceptual knowledge, with the courseware available.

Finally, the interpretation of cluster 4 as a group of teachers stressing "drill and practice" receives additional support. These teachers tended to use microcomputers extensively to help students master basic skills, but not to help them acquire conceptual knowledge. Moreover, they tended to use microcomputers solely in one subject matter (math or science). Indeed, a closer look at the extent to which each cluster uses different types of courseware (e.g., drill and practice, tutorials, simulations), reveals that teachers in this category make most extensive use of drill and practice courseware and least extensive use of other types of instructional courseware. "Orchestrators," on the other hand, make most extensive use of *all* types of instructional courseware, including tutorials, simulations, and microworlds.

Teachers' Attitudes, Knowledge, and Teaching Contexts

Teachers' Attitudes. Teachers' attitudes toward microcomputers were unrelated to the patterns of microcomputer-based instruction that we identified. All teachers held uniformly positive attitudes. In a group of teachers nominated as unusually effective in their microcomputer use, this finding was not surprising.

Teachers' Subject-matter Knowledge. Analyses did not reveal systematic (statistically significant) differences between patterns of use according to the average percent of coursework taken in mathematics, computer science, social science, humanities and education--with one exception. Teachers in the drill and practice cluster took, on average, considerably more coursework in science (47 percent) than did teachers in the other clusters (21 percent averaged over the three clusters).

Teachers' Computer Knowledge. Patterns of microcomputer-based instruction were unrelated to teachers' experience in using microcomputers or teaching other teachers about them, or to their facility with computer languages. Teachers had, on average, used about 25 different educational programs during the school year, applied computers outside their work in a number of different ways (e.g., word processing, data analysis), used several different types of hardware, and wrote in at least one computer language, primarily BASIC. Approximately 70 percent of the teachers had taught other teachers or district staff and 85 percent had served as school resource persons.

Patterns of instructional use did, however, systematically vary as a function of the interviewers' ratings of teachers' *courseware* knowledge. Teachers in the orchestration cluster were rated as significantly more knowledgeable about courseware than teachers in the drill and practice cluster. This finding is, perhaps, not unexpected since the drillers primarily used just one type of courseware whereas the orchestrators were distinguished by their uses of multiple modes of microcomputer-based instruction.

District and School Context. Without exception, the patterns of instructional microcomputer use we observed were *unrelated* to district and school policies regarding their use. Across clusters, most teachers were found, not surprisingly, in districts where (a) the impetus for computers came from teachers, (b) microcomputers were supported, at least to some extent, but (c) microcomputers were not included in the district budget as a line item. About half the teachers were drawn from schools that provided personnel support for computer use, and roughly two-thirds were offered some kind of incentive for using computers--primarily release time to attend computer workshops. By and large, the responsibility for implementing microcomputer-based instruction fell squarely on the shoulders of these "effective" teachers.

Classroom Context. Patterns of microcomputer-based instruction proved to be unrelated to the organizational variables such as the number and location of microcomputers. On average, about 5 computers were available to teachers in the schools studied, but this number varied greatly within a cluster. Slightly over half of the teachers

took their students to laboratories. Variations in instructional pattern were not related to grade level.

In striking contrast was the finding that patterns of microcomputer-based instruction were related to classroom composition. Both percent minority and ability level were associated with instructional pattern ($p<.05$). Students above average in ability and low in percent of minorities tended to be found in teachers' classrooms characterized as "orchestrating" the ongoing curriculum with a wide variety of microcomputer-based instructional modes stressing both skill acquisition and conceptual knowledge. As the ability level decreased and percent minority increased, microcomputer-based instruction tended toward enrichment and adjunct instruction. The five classrooms with a high percentage of minority students (mean=64.40) low in ability (mean=1.20 on a scale from 1 to 5) employed microcomputers to deliver drill and practice on the basic skills taught in class.

SUMMARY AND IMPLICATIONS

To summarize, cluster analyses of various instructional decisions and tasks employed by "effective" microcomputer-using teachers revealed four characteristic patterns of use: "orchestration," "enrichment," "adjunct instruction," and "drill and practice." "Orchestrators" are distinguished by their multiplicity of uses and degree of integration between microcomputer use and ongoing instruction. "Enrichers" appear to encourage student familiarity with the microcomputer within a less ambitious instructional program. "Adjunct instructors" appear to use the microcomputer selectively to enhance conceptual mastery within the subject matter. "Drillers" seem to provide students with an extensive program of drill and practice on the microcomputer to enhance mastery of procedures.

It is important to emphasize at this point that these descriptions characterize teachers who are recognized as "effective." Although our bias might be to favor the orchestrators over the drillers, for example, we are reluctant to state this conclusion without further information. Data on student achievement and motivation would help illustrate whether these different teaching styles with microcomputers produce different outcomes. Observing whether these patterns change over time, or in

response to improvements in courseware availability or quality, would indicate whether there is a "developmental" component to these descriptions. Our goal was to characterize microcomputer use at a time when little is known about how they are used instructionally. We hope that some of the questions raised by this study will stimulate further research on such questions.

Our findings regarding the contribution of characteristics of teachers and learning contexts are perhaps more provocative. A teacher's subject-matter knowledge, especially in mathematics and science, might reasonably be expected to influence patterns of microcomputer-based instruction, especially in those subject matters. This seems to be what some politicians and policymakers had in mind when mathematics and science teachers were suggested as the potential leaders of microcomputer movement in education. However, the fact that "drill and practice" types are most likely to be trained in science may indicate that science training alone may not lead teachers to make the fullest possible instructional use of microcomputers. Our results do indicate that teachers can become effective microcomputer-using instructors regardless of their field of training.

Finally, results relating differences in patterns of microcomputer use according to characteristics of students served raise some concerns. Although there is substantial evidence that low-achieving students need instruction and practice in basic skills, if this is all they receive from microcomputers, their encounters with microcomputers clearly distinguish them from average or above-average students. Put another way, if the "medium is the message," students in classrooms characterized by low ability and high percent of minority students might well learn that microcomputers exist to drill them while other students might learn that the machines can serve them in a variety of ways.

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